

Effect of Oil Prices on Returns to Alternative Energy Investments

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Effect of Oil Prices on Returns to Alternative Energy Investments

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Summary

This paper presents the role of alternative energy technologies in displacing fossil fuels as the world's primary energy source. To that end, a CAPM-GARCH multi-factor market model is used to investigate the relationship between returns on oil and alternative energy stocks. Results show that an increase in oil prices and the broad market have a statistically significant and positive impact on alternative energy stock returns. Furthermore, the alternative energy sector is substantially more risky than the broad market but has the potential for higher returns. This highlights the infancy and inherently risky nature of the alternative energy sector today, but demonstrates the potential for substantial future investment gain as alternative energy technologies become more mature and widely available. Interestingly, estimation of the alternative energy index model indicated the presence of abnormal returns which was not the case for the solar index model, implying that the abnormal returns were generated from a different sectoral component of the alternative energy index.

I. INTRODUCTION

Rising conventional fuel prices and increased public awareness of environmental degradation has caused a renewed interest in the research and implementation of alternative energy technologies over the last decade. During the 2002-2008 period, light sweet crude (the primary constituent of gasoline) experienced a meteoric rise from its low of below \$20 per barrel to nearly \$150 per barrel, sending both consumers and producers of oil dependent nations into a frenzy. Increasing global demand forecasts and dwindling supply concerns combined with political instability in oil producing nations and a gradual decline in the dollar all contributed to the rapid increases in not only light sweet crude, but other conventional energy commodities such as natural gas. This sequence of events emphasized the vulnerability of today's energy markets to factors other than simple supply and demand and the importance of being able to isolate the world's primary energy supplies from future price shocks. Increasing carbon emissions are also cited as a major catalyst for the transition to alternative energy. Atmospheric concentrations of CO₂ have risen steadily from 310ppm in 1950 to over 380ppm in 2009¹. Large CO₂ concentrations in the atmosphere are generally accepted as a major determinant of global warming which has the ability to severely cripple the quality of life on Earth.

It is theorized that the improved commercial viability of alternative energy technologies and the increases in the price of conventional substitutes will ignite the transition from polluting, non-renewable energy technologies to cleaner, renewable sources eliminating much of the world's energy problems. Alternative energy by

¹ Source: National Oceanic and Atmospheric Administration.

definition is emission free and many types of alternative energy derive their fuel from renewable sources. The transition to alternative energy would assure that environmental degradation stemming from fuel byproducts would be minimized and world energy supplies would not be subject to the same volatile price movements as conventional fuels.

Many authors believe rising oil prices should stimulate greater demand and supply of alternative energy², however as of this date, only two studies have been performed which examine the sensitivity of alternative energy sector returns to changes in oil prices.

Previous papers have utilized a standard CAPM approach during periods in which oil prices were slowly increasing. In addition, both papers focus on the individual stocks and alternative energy sector as a whole and not the disaggregated alternative energy types.

The purpose of this paper is to provide an additional empirical analysis of the relationship between the stock prices of alternative energy securities and oil prices analyzing a more recent subset of data using a CAPM-GARCH methodology.

² see for example, Rifkin, 2002; Bleischwitz and Fuhrmann, 2006; McDowall and Eames, 2006; New Energy Finance, 2007

II. ISSUES IN ENERGY MARKETS

The recent and dramatic movement in oil prices in the last six years has sparked considerable debate on the future of oil as the dominant player in the energy sector and the socio-economic and policy benefits of a transition to alternative energy. Figure 1 shows per barrel oil prices from 1940 to present day.

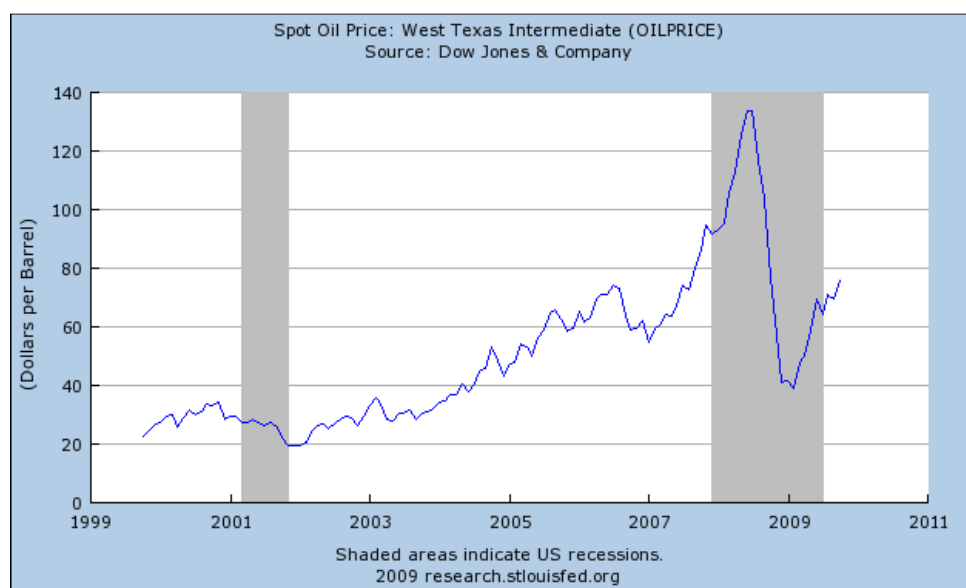


Figure 1. Spot Oil Prices³ (Dollars per barrel)

On a fundamental level, oil prices are determined in the long run by supply and demand like any other commodity, however in the short run, oil prices can be subject to investor speculation, forecast errors and political instability in oil producing regions. Since oil and certain oil derived products are an element of the CPI index, the effect of oil price volatility on CPI inflation is immediately felt, however oil price shocks can also

³ Courtesy of the Federal Reserve Bank of St. Louis

have a downstream impact on other commodity prices which may also precipitate a lagging effect on CPI inflation.⁴

Examining historical oil price shocks such as those that occurred during the late 1900s have revealed a fairly consistent side effect; that is, all of the major oil price shocks during this period have been followed by periods of recession and rapid rebounds. This rapid volatility makes monetary and fiscal policy actions inherently difficult to plan and implement due to policy lag and the potential for overcorrection. Oil price shocks can also bring about unexpected changes in transportation costs at the consumer and supplier level decreasing buying power and increasing the prices of goods and services. Since oil is used as an input in the production of many goods, rising oil prices increase the marginal costs of the relatively more oil-dependent goods production processes. High oil prices also have a direct impact on all stages of food production from transportation to capital to input costs.⁵ It is hoped that the transition to alternative energy will alleviate some of these uncertainties and negative effects on the economy.

The alternative-energy segment of the energy industry covers a broad range of sources. While the definition of alternative energy varies by source, it is often stated that only energy sources without “undesired consequences” (i.e. substantial carbon footprint, radioactive waste, etc.) can claim this moniker. These sources range from the presently competitive with fossil fuels to those still within the experimental stage of development, presenting a potentially larger risk / reward for investors. Such energy sources include but are not limited to:

⁴ see for example, Cunado and Perez 2005

⁵ Ironically, the recent rise in light sweet crude precipitated a U.S. policy action which diverted corn and other potential food crops to ethanol production in an effort to combat the oil prices increases further exacerbating the food shortage and doing very little to combat fuel price increases.

- Biomass Energy (organic growth and/or byproduct)
- Wind (air in motion)
- Solar (for heating and electricity production)
- Hydropower
- Hydrogen Fuel Cells
- Geothermal (natural heat generated by the earth's core)
- Marine (wave energy and tidal barrages)
- Nuclear fission⁶

Since 2004, annual worldwide renewable energy investment has increased fourfold to reach \$120 billion in 2008. In the four years from 2004 to 2008, solar photovoltaic (PV) capacity has increased six fold to more than 16 gigawatts (GW), wind power capacity increased 250 percent to 121 GW, and total power capacity from new renewables has increased 75 percent to 280 GW, including significant gains in small hydro, geothermal, and biomass power generation. During the same period, solar heating capacity doubled to 145 gigawatts-thermal (GWth), while biodiesel production increased six fold to 12 billion liters per year and ethanol production doubled to 67 billion liters per year. Annual percentage gains for 2008 were even more dramatic. Wind power grew by 29 percent and grid-tied solar PV by 70 percent. The capacity of utility-scale solar PV plants (larger than 200 kilowatts) tripled during 2008, to 3 GW. Solar hot water grew by 15 percent, and annual ethanol and biodiesel production both grew by 34 percent. Heat and power

⁶ The inclusion of nuclear fission as an “alternative” energy is debated due to its harmful byproducts.

from biomass and geothermal sources continued to grow, and small hydro increased by about 8 percent.⁷

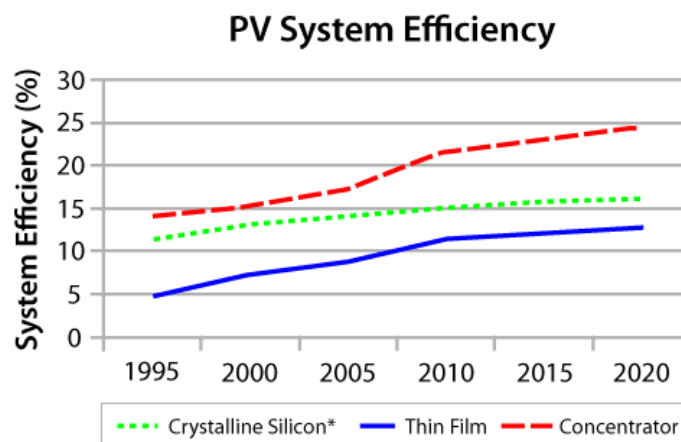
New alternative energy technologies are attempting to enter into different markets, often in competition with incumbent energy types to fulfill the demand for energy generation. As with any other competing technology, the successful adoption of alternative as a major component of the world's energy infrastructure will depend on the economic and political competitiveness with conventional sources. One manner in which this is achieved is if the price of substitutes, in this case oil, were to increase causing alternative energy to become a less expensive alternative. This could be achieved in a variety of ways such as through carbon-controlling regulation making carbon-generating energy sources competitively more expensive to their carbon-neutral counterparts. Currently being debated in Congress are the possibilities of carbon taxes and a cap and trade system which are widely regarded as the most effective and economically motivated regulatory means of reducing CO₂ emissions. With a cap and trade system, companies that hold their emissions below the cap are allowed sell their remaining allowance on a carbon market. Companies that exceed their cap can purchase allowances on the carbon market. This system increases the costs of producing a carbon intensive good. Producers of carbon based products either cut production or incur abatement costs to reduce carbon emissions. In either case, the supply curve for carbon based energy sources shifts to the left, raising price and reducing quantity.

Carbon taxes are taxes levied on carbon emissions generated from the combustion of fossil fuels (Poterba, 1993; Harris, 2006). A carbon tax is determined to be a fixed amount per ton of coal or barrel of oil. The supply curve for carbon based energy sources

⁷ See Renewable Energy Global Status Report update, 2009

shifts to the left, raising the price of carbon based energy sources and reducing the quantity demanded (Harris, 2006, Fig. 18-7). The tax burden that is shared between producers and consumers of carbon based energy sources depends upon the relative elasticities of demand and supply. The carbon tax would appear to consumers as an energy price increase. Such taxes and systems have already been put into place by some governments making the effects of this phenomenon historically quantifiable.

Another manner in which alternative energies could become more economically competitive with conventional sources is through the maturation and economies of scale of alternative energy technologies. Solar photovoltaics are one sector of the alternative energy industry already showing substantial increases in efficiency, declines in capital costs and overall reductions in energy costs. Figure 2 shows recent and projected trends in these areas.



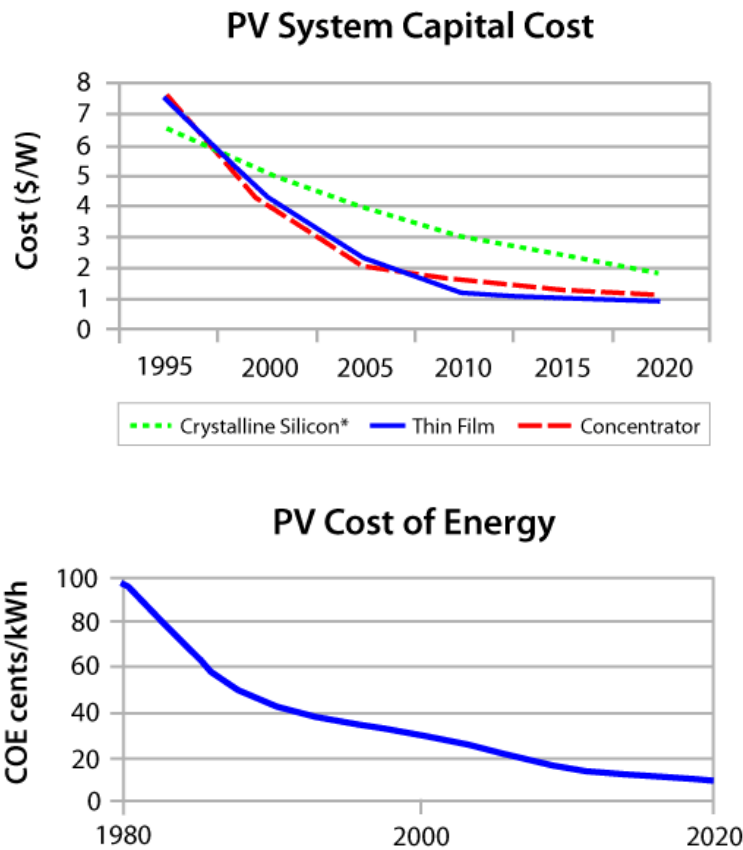


Figure 2. Costs and efficiencies for leading solar technologies⁸

Currently, the three most commercially viable⁹ sources of alternative energy are nuclear, hydroelectric, and wind energy. Due to the substantial long-term planning required and the potential for political considerations to stall the development of nuclear power plants and new dam projects in developed countries, nuclear energy and hydroelectric power are most likely subject to more rapid adoption in rapidly developing countries. Wind energy, benefits from being an established technology and a renewable energy source resulting in a rapid growth over the past decade, especially in Europe, where political incentives to develop a wind infrastructure have been particularly strong.

⁸ Courtesy of the U.S. Department of Energy

⁹ Viable implies that their cost per kilowatt hour is comparable to that of fossil fuels.

Wind power is likely to become more prominent if turbine technologies can improve in efficiency and alleviate the inherent problem stemming from intermittency. The move towards distributed energy, in which is energy supplied on a more local scale rather than through a national grid, may spark interest in the biomass segment, solar power and hydrogen-powered fuel cells. The latter two are still expensive versus traditional fossil fuel sources, with commercial viability resting on improved technologies. In spite of higher costs, both industries have been experiencing steady growth. Unlike more established industries, these technologies offer more attractive potential returns at a higher risk.

III. LITERATURE REVIEW

The existing literature highlights the use of several econometric techniques for the purpose of describing the risk relationship of stock prices to the market and choice variables. While it is intuitive to think that rising oil prices precipitate a substitution effect in correspondence with alternative energy investment, as of this date, only two papers have been published that measure the sensitivity of alternative energy investment vehicles in response to oil price shocks. Henriques and Sadorsky 2007 utilizes a vector autoregression to empirically investigate the Granger causality between specific alternative energy ETF's and oil prices. Their results indicate the stock prices of alternative energy companies to be impacted by shocks to technology stock prices but shocks to oil prices have little significant impact on the stock prices of alternative energy companies. Truck 2008 presents a study utilizing a CAPM and multifactor approach to investigate the relationship between individual alternative energy stocks and oil prices. His results indicate that for select periods when the oil price was rising, the models on average only explain around 10% of the variation in returns from renewable energy companies and significant abnormal returns for the companies could not be observed. On the other hand, for his applied factor model, a clearly higher number of the oil coefficients were found to be significant in particular for companies in the fuel cell and photovoltaic industry.

Despite their conclusions, the authors acknowledge the need for more substantive research on the subject of alternative energy stock prices. In particular, with the economic events of the last several years, it is possible that different modeling

methodologies and additional data series could provide contrasting results. For instance, it is well documented that asset returns exhibit volatility clustering¹⁰. Momentum of stock price changes often demonstrates that large price changes are often followed by large price changes and small price changes are often followed by small price changes thus leading to a non-constant conditional variance. A popular approach that allows for variable, non-contemporaneous conditional variance specification is the autoregressive conditional heteroskedasticity (ARCH) models and its variants.¹¹ The previous alternative energy risk studies published by Sadorsky and Truck utilize traditional CAPM methods and find no abnormal returns in the alternative energy sector, but even with the reported heteroskedasticity-adjusted standard errors, it is possible that these analyses are not particularly robust to the data characteristics.

Harrington (1983) examines the risk/return relationship for life insurance stocks using traditional CAPM and reported no conclusive evidence for the existence of abnormal returns. On the other hand, Hatfield (1997) finds that life insurance stock returns outperform the market on a risk adjusted basis for their estimation period, an ambiguity from the Hatfield study. Evidence in favor of a CAPM-ARCH specification comes in the form of a study conducted by Jagannathan and Wang (1996) that shows utilizing a CAPM-GARCH specification explains a greater cross-sectional variation in stock returns than traditional CAPM methods. In addition, Durack et al. (2004) applies a CAPM-GARCH model to Australian stock data and reports that the explanatory power of the traditional CAPM rises from 7.25 to 65.31 percent. This collection of evidence strongly

¹⁰ See Andersen (1996), and Andersen and Bollerslev (1997)

¹¹ See Engle (1982) and Bollerslev (1986).

favors the use of a CAPM-ARCH model in modeling the risk/return relationship of alternative energy securities.

IV. HYPOTHESIS & METHODOLOGY

It is clear that with noticeable share gains in the infancy of alternative energy adoption that there exists a potential for substantial investment gain in the coming years; but are these dramatic increases in adoption and capacity the result of a natural progression or in response to the oil price increases of the last several years? If the latter is the case, there should be a detectable relationship between the stock returns of alternative energy firms and oil returns. Intuition would suggest that rising oil prices would induce a gradual substitution away from oil and into alternative energy sectors as this sector becomes comparatively less expensive *ceteris paribus*, however since the price of oil can induce a multitude of macroeconomic and market effects as described previously, the effect of oil prices on the stock prices of alternative energy companies is not so clear and must be tested.

A model for relating the value of alternative energy indices to various risk factors can be constructed using a multifactor market model (Sadosrsky 2001). An oil beta can be calculated by estimating the following CAPM-GARCH multifactor market model of which the conditional mean is given by:

$$R_{it} = \alpha + \beta_s R_{st} + \beta_o R_{ot} + \varepsilon_t \quad (1)$$

where R_{it} is the weekly excess equity returns on the alternative energy index, R_{st} is the weekly excess return on the market index, R_{ot} is the monthly return to oil prices and ε_t is the disturbance. The parameters β_s and β_o are the market beta and oil beta respectively.

The intercept α determines whether the modeled asset (dependent variable) outperforms or underperforms the market on a risk adjusted basis. A positive and significant value of α reflects outperformance while a negative significant value of α reflects underperformance. The conditional error variance of the model in equation 1 is chosen as a GARCH (1, 1)¹² such that the specification is given by:

$$\sigma_t^2 = \theta_0 + \theta_1 \varepsilon_{t-1}^2 + \theta_2 \sigma_{t-1}^2 \quad (2)$$

$$\varepsilon_t \sim N(0, \sigma_t^2)$$

where the θ 's are parameters.

¹² GARCH is an extension of ARCH in which one can specify the conditional variance as a function of both the lagging squared disturbance and error variance respectively. The numbers in parenthesis correspond to the order of each.

V. DATA

The Powershares WinderHill Clean Energy ETF (PBW) is used to measure the stock market performance of alternative energy companies. This ETF consists of approximately 40 companies engaged in the alternative energy (hydrogen fuel cells, wind, solar) industry. As the moniker suggests, PBW is based upon the WinderHill Clean Energy Index. The individual sectors of the alternative energy industry of particular interest, but as of this writing, there exists only one sector index with data over a useable time period, that is the MAC Global Solar Index (MAC). The index tracks the stock prices of 30 solar energy companies with a median market capitalization of 650 million dollars. Daily data from this index is available from the MAC Indexing LLC website. Figures 3 and 4 plot the daily returns of the WinderHill Clean Energy Index and the MAC Global Solar Index.

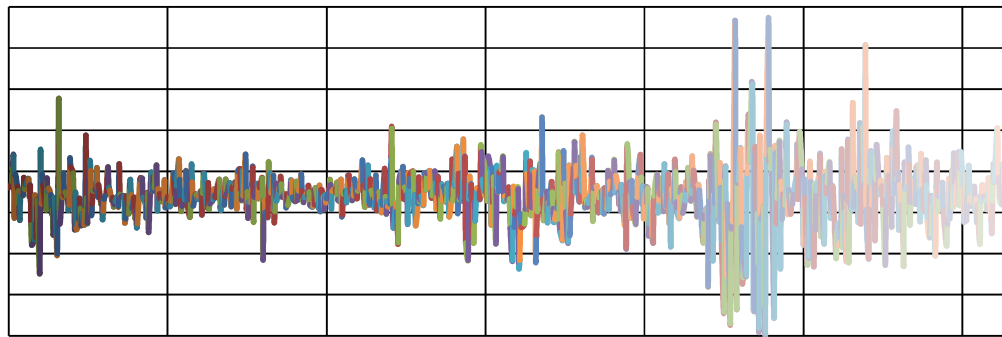


Figure 3. MAC Global Solar Index Daily Returns

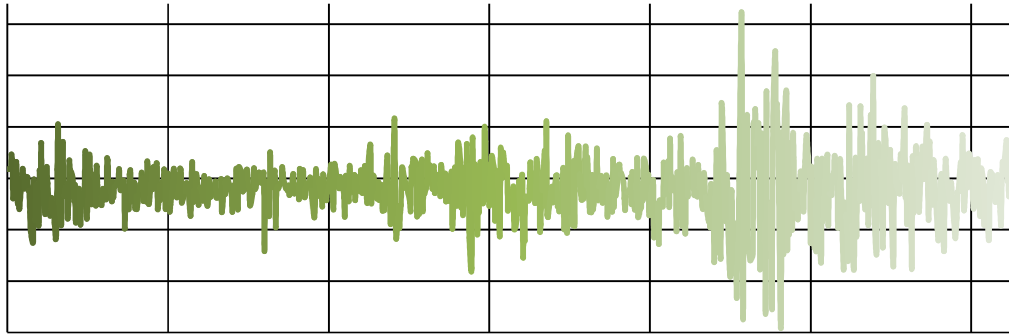


Figure 4. WinderHill Clean Energy Index Daily Returns

Note that in both cases, high degrees of volatility in returns are clustered in certain portions of the data series confirming the ARCH series of models a highly robust model choice in this case.

The SPDR Trust (SPY) is used to track the performance of a benchmark index. The SPDR Trust is an exchange-traded fund that holds all of the S&P 500 Index stocks and is comprised of undivided ownership interests called SPDRs. The investment seeks to correspond generally to the price and yield performance, before fees and expenses, of the S&P 500 Index. The SPDR Trust is necessary to model the risk and reward of alternative energy indices against the market.

Oil prices are represented by the United States Oil Fund (USO) ETF. USO is a domestic exchange traded security designed to track the movements of light, sweet crude oil (West Texas Intermediate). The parent company invests in futures contracts for light, sweet crude oil and other types of crude oil, heating oil, gasoline, natural gas and other petroleum-based fuels that are traded on the New York Mercantile Exchange (NYMEX), International Currency Exchange (ICE) Futures or other United States and foreign exchanges.

Risk-free rate data was obtained from the Federal Reserve Bank of St. Louis and was specified to be the 3-month U.S. Treasury Bill annual percentage rate. Previous business cycle research has highlighted the importance of interest rates in *explaining* stock price movements¹³, however it is intuitive to consider that due to the efficient market hypothesis, interest rates are already reflected in the valuations of stocks and introducing a new interest rate variable would not yield new information. Indeed, several papers have highlighted the lack of significance of interest rates in multi-factor market models.¹⁴

ETF data is obtained from Yahoo! Finance. MAC solar index data is obtained directly from MAC Indexing LLC. All data spans from April 2006 to September 2009 yielding 173 weekly observations¹⁵. Though daily data was available, weekly data provides a useful middle ground between the high degree of daily data noise and the limited number of monthly observations. Summary statistics are given in table 1.

Table 1. Summary statistics for weekly returns

	PBW	MAC	USO	SPY
Mean	0.0063	0.0065	0.0049	0.0018
Median	-0.0035	0.0037	-0.0109	-0.0034
Maximum	0.3933	0.4817	0.2389	0.2332
Minimum	-0.1824	-0.2498	-0.1083	-0.1155
Variance	0.0049	0.0088	0.0029	0.0013
Skewness	2.2110	1.6246	0.8683	2.7172
Kurtosis	12.7033	8.7958	4.9839	19.1493
W	0.8251***	0.8788***	--	--

The Shapiro-Wilk normality test statistic is given by W. (***) indicates significance at the one percent level.

¹³ see Chen 1991, Chen et al. 1986, Sadorsky, 1999, 2001

¹⁴ notably, Sadorsky 2001, 2008

¹⁵ Wednesday closing prices were chosen as weekly prices due to the fewer holidays which fall on Wednesdays compared to other days of the week. Missing data on Wednesdays was replaced with closing prices from the most recent trading session.

Weekly ETF and index returns were calculated from the following formula:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}}$$

where P is the ETF price at closing. Risk-free rate annual percentage rate data was converted to a weekly rate via the following formula:

$$R_w = (1 + R_a)^{1/52} - 1$$

where R_a is the annual percentage rate.

Shapiro-Wilk tests for normalcy indicate that the null hypothesis of normalcy is rejected at the 1% level for the dependent variable data series. This result is confirmed by a skewness/kurtosis test for normality. Large kurtosis values of stock returns indicate leptokurtosis which is consistent with other samples of asset returns in literature¹⁶. These results strongly favor the use of CAPM-GARCH as the appropriate model. Table 1 presents summary statistics for the four data series.

A time series plot of the MAC Global Solar Index (MAC), the WinderHill Clean Energy Index (PBW), the United States Oil Fund (USO), and the S&P 500 Index (SPY) is shown in Figure 5. For ease of data comparison, each series is normalized to 100 in April of 2006.

¹⁶ See Engle (1982), Bollerslev (1986), and Bollerslev et al. (1992).

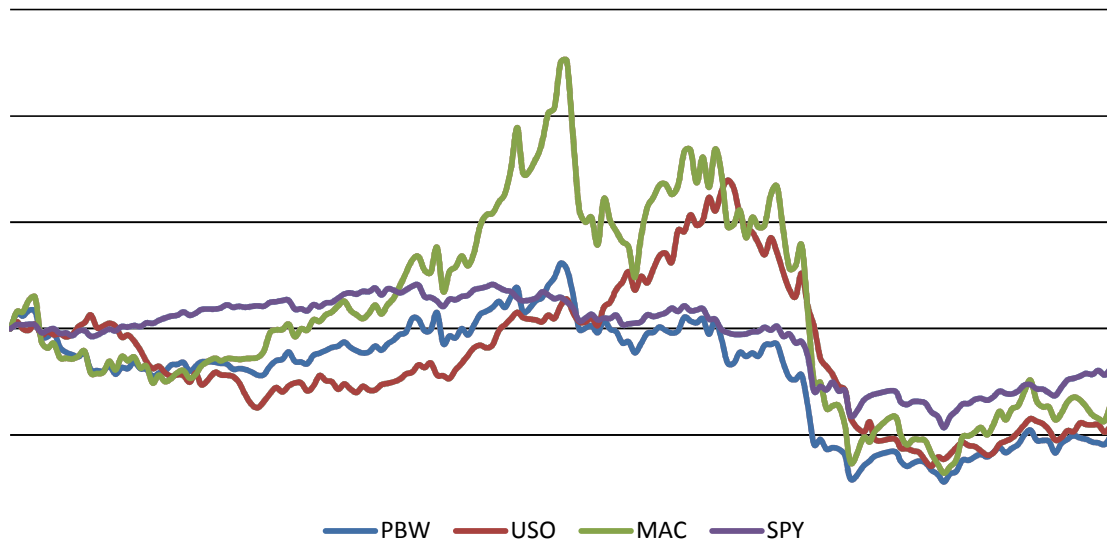


Figure 5. PBW, USO, MAC, SPY

It is useful to note that during the estimation period, neither alternative energy instrument nor oil outperformed the S&P 500 and all were more volatile. The MAC index exhibited the highest volatility but rewarded investors appropriately if sold before the market downturn at the end of 2007. The lackluster performance of the WinderHill index is surprising given that its portfolio contains several of the same stocks as the MAC index. This could indicate that the other alternative energy sectors are less risky than the solar sector.

VI. RESULTS

Market risk comparisons are investigated using the multifactor model described in equation 1. These models are useful for explaining the risk/return relationship between alternative energy investments, oil prices and the broad market when all variables are measured contemporaneously. Regression diagnostic tests indicate negligible autocorrelation of the residuals¹⁷. Lagrangian multiplier tests for ARCH(1) effects indicate that the null hypothesis of no ARCH(1) effects is rejected. Table 2 presents market risk comparisons for two single-factor and multi-factor models each involving two dependent variables.

Table 2. Market Risk Comparisons

Conditional Mean	$R_{it} = \alpha + \beta_s R_{st} + \beta_o R_{ot} + \varepsilon_t$			
	PBW	PBW	MAC	MAC
Constant	0.0042 (1.65)*	0.0051 (1.92)*	0.0000 (0.27)	0.0000 (0.47)
Market	1.63 (19.01)***	1.69 (27.02)***	1.95 (12.99)***	2.04 (15.43)***
Oil	0.16 (3.62)***	- -	0.28 (4.05)***	- -
R ²	0.75	0.73	0.64	0.59
LM	7.42(***)	7.01(***)	6.53(**)	5.68(**)
DW	2.33	2.23	2.32	2.18
F _p	0.00	0.00	0.00	0.00
Conditional Variance	$\sigma_t^2 = \theta_0 + \theta_1 \varepsilon_{t-1}^2 + \theta_2 \sigma_{t-1}^2$			
ARCH(L1)	0.14 (2.61)***	0.13 (2.44)**	0.13 (2.33)**	0.12 (2.11)**
GARCH(L1)	0.84 (18.09)***	0.85 (17.04)***	0.85 (16.74)***	0.85 (15.43)***
Constant(ARCH)	0.00 (1.03)	0.00 (0.99)	0.00 (1.34)	0.00 (1.54)

¹⁷ See Wooldridge (2008).

The first cell for each variable contains the coefficient estimate and the second cell contains the t statistic. DW refers to Durbin-Watson statistic, LM refers to the Lagrangian multiplier test for ARCH(1) effects, F_p is the probability value for an F test that all slope coefficients are equal to zero. R^2 indicates its adjusted constituent. (*), (**), (***) indicates significance at the ten, five, and one percent levels respectively.

The estimated coefficient on the market return variable indicates that the WinderHill Clean Energy Index is systemically, approximately 69% more risky than the broad market index (S&P 500) during the estimation period. Similarly, the estimated coefficient on the market risk variables indicates that the MAC Global Solar Index is systemically, approximately 104% more risky than the S&P 500 during the estimation period.¹⁸

The oil price betas are positive and statistically significant for both the alternative energy and solar models. This result provides evidence to support the conjecture that oil price movements impact alternative energy stock returns. The oil price beta for MAC is nearly twice that of PBW indicating that solar sector returns are more sensitive to changes in oil prices than the broad alternative energy market. This is most likely due to the large percentage of more volatile small cap stocks and startup solar companies that comprise the MAC solar index. Conversely, the WinderHill index contains a larger share of large cap, multinational corporations.

The constant terms for the solar index model are statistically zero which implies that solar energy stocks do not outperform the market on a risk-adjusted basis, however constant terms for the alternative energy index show positive significance indicating the presence of abnormal returns for this period. This could imply that other alternative energy sectors other than solar possess the potential for abnormal returns.

¹⁸ The estimation period covers a comparatively volatile market event from peak in December of 2007 to the subsequent crash of 2008. This may cause many of the estimated coefficients to be higher than expected given an ordinary period of steady market growth.

The adjusted R^2 values for PBW and MAC indicate that 75% and 64% of the variation in alternative energy and solar returns respectively can be explained by market returns and oil price returns. These models have slightly higher explanatory power than the single-factor market models.

The estimated ARCH and GARCH coefficients are found to be both positive and statistically significant validating the appropriateness of the CAPM-GARCH specification. In particular, the estimated GARCH coefficients of 0.84 and 0.85 indicate that volatility of returns is a highly persistent phenomenon on a weekly basis.

VII. CONCLUSION

This paper uses a CAPM-GARCH multi-factor market model to investigate the relationship between oil prices and alternative energy indices. The results indicate that alternative energy index returns are sensitive to broad market returns and oil price returns. In particular, an increase in the return to oil or the broad market increases the return to alternative energy stocks. This is consistent with the results reported by Sadorsky 2008 and Truck 2008. Furthermore, the alternative energy sector as a whole and the solar sector are respectively, 69% and 104% more risky than the broad market during the estimation period. This represents a nearly two-fold increase in volatility from those results reported by Sadorsky, most likely due to the inclusion of recent data factoring into account increased volatility of financial markets during the recent series of financial institution collapses and negative economic growth.

Interestingly, estimation of the alternative energy index model indicated the presence of abnormal returns which was not the case for the solar index model, implying that the abnormal returns were generated from a different sectoral component of the alternative energy index. This differs from previous studies conducted by Sadorsky 2008 and Truck 2008 which concluded that virtually no abnormal returns were generated from alternative energy companies. This could be due in part to their utilization of traditional CAPM methods instead of the more robust CAPM-GARCH.

Further research in this area should investigate the Granger causality of the solar index returns as in the case of Sadorsky's 2008 analysis. It will also be worthwhile to repeat this study during a less turbulent financial period and with a longer data series. As

of this writing, sector-based alternative energy indices are a relatively new phenomenon and thus do not have sufficient observations for useful statistical conclusions to be drawn. As these indices include more observations, it would be of interest to compare the risk relationship of all alternative energy sectors. Nevertheless, abnormal returns coupled with the potential for rapid growth in the alternative energy sector and the future projected increases in oil prices suggest that alternative energy stocks should be a component of a well-diversified portfolio.

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